"The certainty of our predictions about restoration varies by habitat type. We will learn and adjust as we go forward."

—Michelle Orr, PWA

Science, Learned & Needed

"Revegetation is working to restore a diversity and abundance of songbird populations along the Sacramento, Cosumnes, and San Joaquin Rivers."

—Geoff Geupel,
PRBO Conservation Science

Photo courtesy of David Hart and John Sanger

A Landscape Ecology Perspective on Bay Wetland Restoration

MAGGI KELLY
UNIVERSITY OF CALIFORNIA, BERKELEY

San Francisco Bay is the largest estuary on the Pacific Coast; its wetlands provide crucial habitat for a wide range of species, and have a long history of human impacts. The wetland landscape is a complex mosaic of remaining historic wetlands, recently restored wetland sites, and potentially restorable diked bayland sites (farms, former salt ponds, and managed and unmanaged seasonal and perennial wetlands), all arranged in one of the state's largest urban areas. The diverse mosaic separating Bay from upland is crucial in many ways to the future of the San Francisco Bay Area: for example, these wetlands are an important component of the Bay's ecology, and they are part of the natural open space valued by a highly urban population.

While it has long been recognized that wetlands are ecotonal features between upland and open water, we also think of this complex of wetlands in the greater San Francisco Bay as wetland patches with ecotonal areas between them, and displaying within-patch variability that is important for species (bird, fish, mammal, etc.) diversity and survival, and other wetland functions. A landscape ecology approach is useful for setting the stage for large-scale wetland restoration in the Bay; the approach incorporates multiple scales and considers interactions between patches and flows between and across ecotones and patches. Landscape ecological principles such as adjacency, connectivity, heterogeneity, and spatial configuration can be useful guiding principles for future restoration.

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TAKE HOME POINTS

- **By increasing the spatial scale we use, landscape ecology can help us see how individual wetlands function together. It can also help us determine how existing marsh patches can be revisualized for certain species.**
- **On a temporal scale, the future of the Bay—a mosaic of wetlands in an increasingly urbanized watershed—has to be planned for.**
- **We need a vision for planning for the ecosytem services provided by wetlands. Context and adjacency affect wetland functions.**

Predicting Habitat Changes in Wetland Restoration

MICHELLE ORR, ET AL.
PHILIP WILLIAMS & ASSOCIATES

Tools that integrate system-wide physical and ecological processes can be useful for large-scale restoration planning by informing decisions about where, how much, and which types of habitat to restore. In the 15,100-acre South Bay Salt Pond (SBSP) Restoration Project in South San Francisco Bay, successful design requires an understanding of how the ecosystem will evolve over time in response to possible management actions such as restoring tidal inundation to salt ponds to create tidal marsh.

The SBSP Landscape Scale Assessment is a geomorphic approach to predicting long-term (50-year) habitat changes within South San Francisco Bay without restoration as well as for different restoration scenarios. Given the inherent complexity of the processes involved, there are no standard "off the shelf" tools for this type of prediction. The assessment combines a sediment budget approach with existing analytical models, historical analysis, and empirical tools. The project planning timeline precluded development of new detailed models, such as a fine-grid numerical model, for the assessment. The physical-processes part of the assessment is an examination of the rate at which the restored South Bay salt ponds are expected to evolve from tidal mudflat to marsh, and how the restoration may affect the South Bay sediment budget and ultimately the extent of tidal mudflat and shallow-water habitats within the South Bay. The ecological part of the assessment uses the physical-processes results to predict vegetation, habitats, and wildlife use. Even when the large uncertainty inherent in this kind of assessment is considered, preliminary results suggest that sufficient sediment is available for tidal marsh restoration and that even the most subsided ponds are expected to provide tidal marsh habitat within the fifty-year planning horizon.

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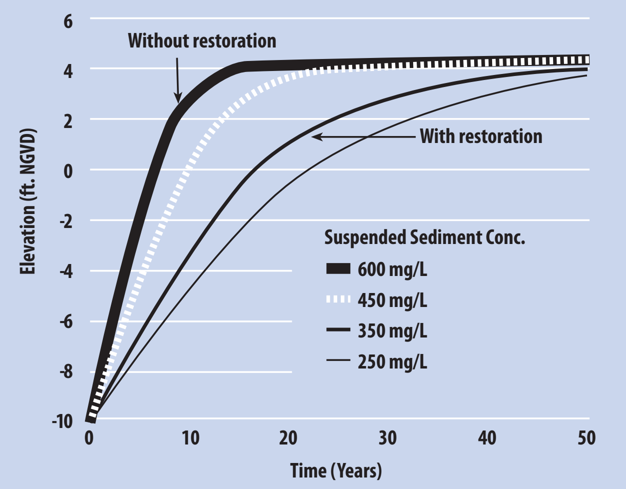
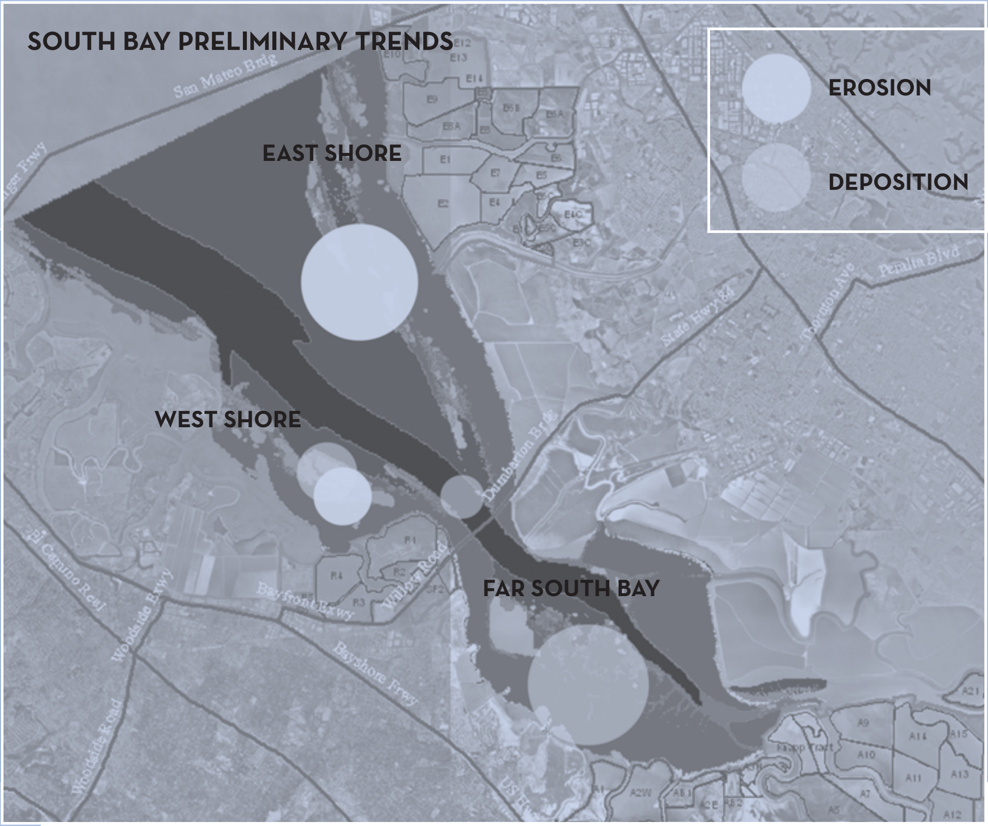
HABITAT EVOLUTION IN THE TIDAL PONDS: LONG TERM SEDIMENTATION



TAKE HOME POINTS

- The certainty of our predictions about restoration varies by habitat type.
- Our restoration plan must be resilient.
- We will learn and adjust as we go forward.

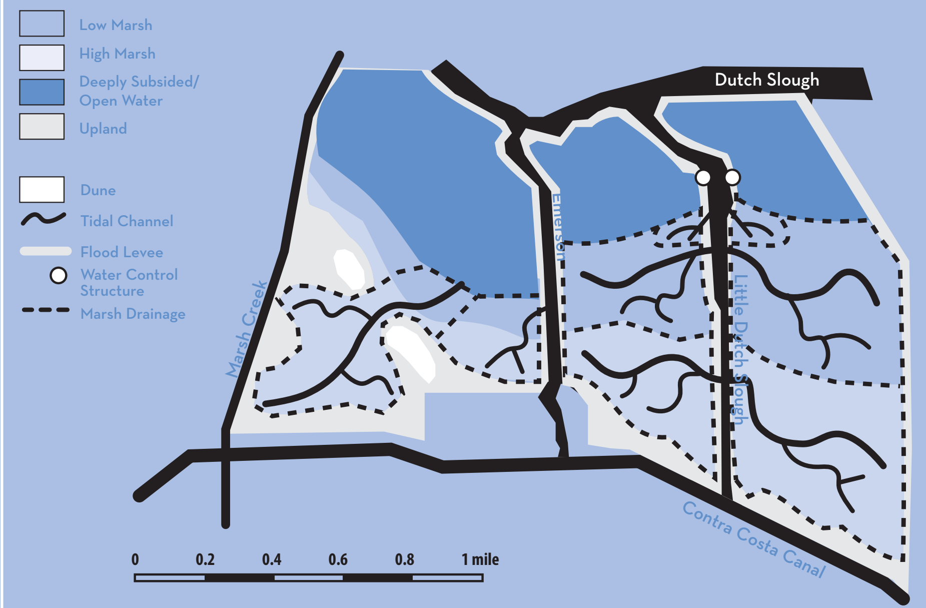


Dutch Slough: Restoration and Adaptive Management

JOHN CAIN
NATURAL HERITAGE INSTITUTE

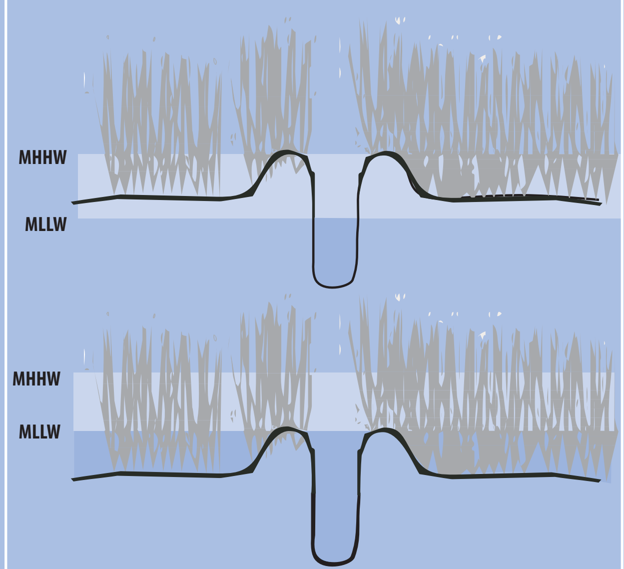
The CALFED Bay Delta Authority and the State Coastal Conservancy provided $28 million to acquire a 1,166 acre parcel along Dutch Slough in northeastern Contra Costa County for tidal marsh restoration. The parcel was previously levied dairy and ranch land that was slated for development of 4,500 residential units. The California Department of Water Resources has assumed ownership responsibilities and is working collaboratively with the State Coastal Conservancy, CALFED, the Natural Heritage Institute, and the City of Oakley to plan and implement the restoration project within an adaptive management framework. The goals of the project are to: 1) provide shoreline access, recreational, and educational opportunities, 2) restore a mosaic of wetland and upland habitats for native species, and 3) increase understanding of ecosystem function through an adaptive management approach.

DUTCH SLOUGH TIDAL MARSH RESTORATION - ALTERNATIVE 2B



The property is divided into three levied tracts that could be separately treated and restored to tidal action in a unique opportunity to design the restoration project as an adaptive management experiment. The project partners are working with an interdisciplinary group of scientists to physically design the project to test hypotheses regarding the role of marsh plain elevation and associated inundation frequency in 1) avian utilization; 2) growth and survival of juvenile salmon and splittail; 3) colonization of submerged aquatic vegetation; 4) production and flux of methyl mercury and dissolved organic carbon; and 5) the role of vegetation in freshwater marsh plain accretion and slough channel evolution. Different portions of the project site will be restored to different marsh elevations in an attempt to isolate the role of marsh plain elevation in these various processes.

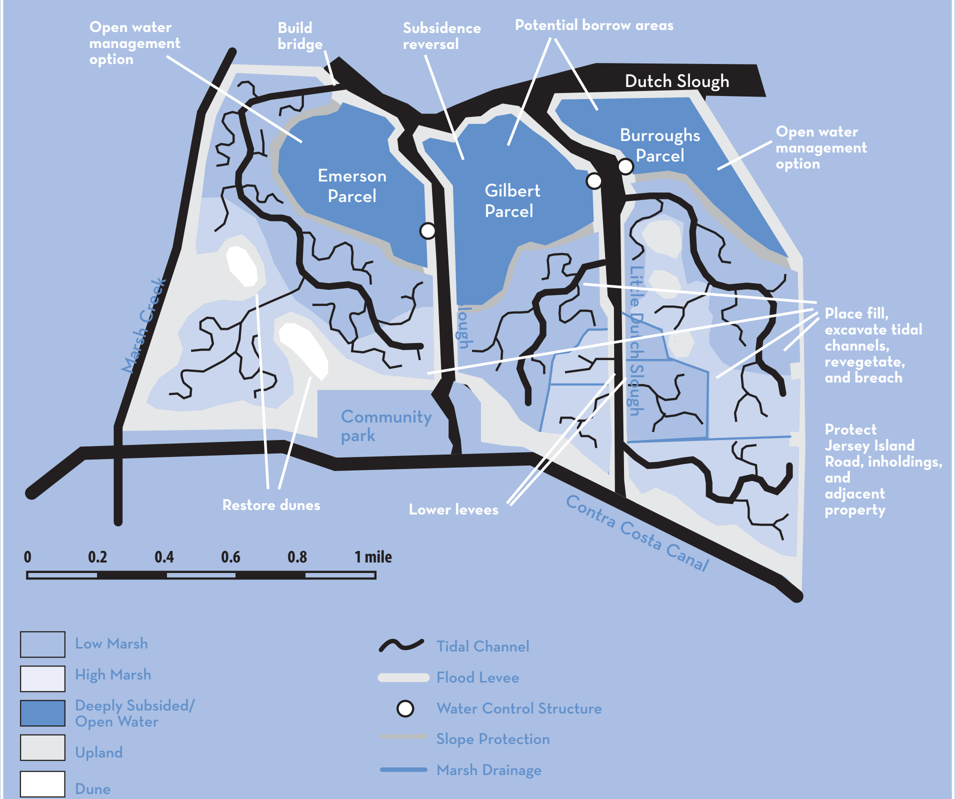
HOW LOW SHOULD WE GO?



TAKE HOME POINTS

- **Restoration is contagious—we have new partners every day. Yet all of our restoration efforts will be relatively futile if we are unable to stem the tide of urbanization in the Delta.**
- **Restoration can wait, but the time for acquisition is now.**
- **We need to expand the Delta Protection Commission to protect the Delta's secondary zone from development.**

DUTCH SLOUGH TIDAL MARSH RESTORATION - ALTERNATIVE 3



The planning process has revealed several challenges and potential tradeoffs that can arise when designing a restoration project as an adaptive management experiment. Designing an experiment into the restoration design is an ideal opportunity to learn but can create conflicts between optimal experimental design and optimal restoration design. For example, dividing the restoration site into numerous cells of different elevations could help tease out the role of elevation in numerous ecosystem processes, but fragmentation of the site into smaller cells could reduce connectivity of various habitat types and potentially preclude important scale dependent processes.

Adaptive management presumably implies that managers will change their management if the project does not perform as desired. This paradigm makes obvious sense with efforts to manage fishery harvest, cattle grazing, or exotic species, but is more complicated for capital intensive earth moving projects in highly regulated environments. If the initial design does not perform as desired, is it realistic to assume that managers will or should physically modify the Dutch Slough restoration? Or should the Dutch Slough project be viewed as a one time management intervention designed to inform future restorations in the larger Bay-Delta system?

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QUESTIONS WE HOPE TO ANSWER:

What is the relationship between marsh plain elevation and

- Salmon and splittail growth and survival
- Fish food production and availability
- Splittail and Delta smelt spawning
- Mercury methylation
- Dissolved organic formation and export

What is the relationship between marsh scale and channel order and

- Salmon and splittail growth and survival
- Fish food production and availability
- Splittail and Delta smelt spawning

OUR HYPOTHESES:

- Juvenile salmon and splittail will have higher survival rates on high marsh because there will be fewer fish predators.
- Food resources will be greater in lower marsh due to increased residence times.
- Fish survival will be greatest with intermediate scale channel network because higher order networks will harbor predators, and lower order networks lack sufficient refuge during low tides.

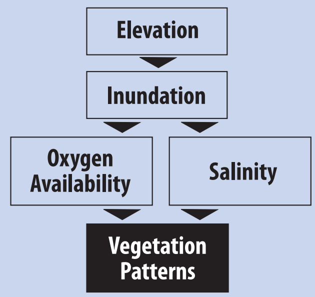
Elevation, Inundation, Vegetation — and Restoration

JOHN CALLAWAY, ET AL.
UNIVERSITY OF SAN FRANCISCO

Tidal wetland restoration efforts have focused on establishing the appropriate elevation for plant colonization, with the assumption that elevation determines inundation rates and other critical factors for plant establishment and growth, including soil redox status and salinity. While elevation is the key factor driving inundation rates, within-site variation due to impoundments, pannes, and other features may affect local flooding and draining. Substantial research has evaluated elevational distributions of tidal wetland plants in San Francisco Bay wetlands; however, very little work has directly linked elevation to patterns of inundation across a tidal wetland.

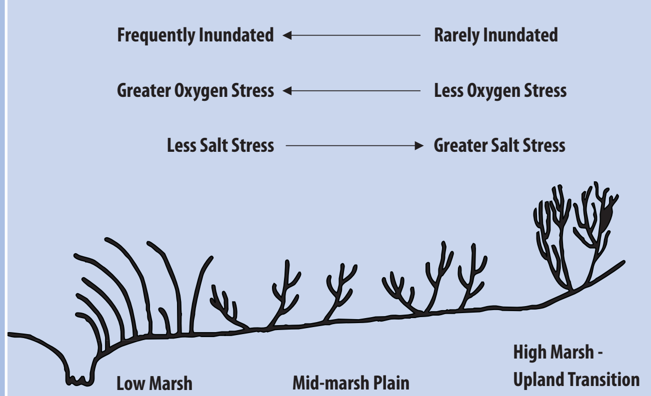
As part of the Integrated Regional Wetland Monitoring Program (IRWM), we evaluated distributions of plant species across six tidal wetlands in the north San Francisco Bay Estuary, working closely with the IRWM Physical Processes Team to connect these distributions to elevation and inundation patterns across each wetland. Plant distribution and elevations were determined at 200-500 locations in each wetland and were related to inundation patterns from three to four water level stations on the marsh plain. Inundation data were collected for approximately one year at each wetland and were also compared to water level data from instruments in adjacent tidal channels.

FACTORS AFFECTING VEGETATION



Patterns of vegetation zonation were apparent from our data, with species showing peaks in distributions across the tidal wetlands. For example, at Coon Island, *Salicornia virginica* had the most widespread elevational distribution, with a number of species occurring at slightly lower elevations, including *Spartina foliosa*, *Typha angustifolia*, *Bolboschoenus maritimus* (formerly *Scirpus maritimus*), and *Schoenoplectus acutus* (formerly *Scirpus acutus*). There was substantial overlap and spatial variability in both the elevational distributions and inundation patterns for some of the dominant species, including *S. acutus*, *Schoenoplectus californicus* (formerly *Scirpus californicus*), and *T. angustifolia*. We found little evidence for critical thresholds for plant distributions across all wetlands. Other factors that are likely to affect distribution include soil salinity (being measured this year), initial vegetation establishment, and competition. With the IRWM Bird Team, we also are comparing vegetation patterns to bird use so that we can evaluate how inundation affects habitat characteristics that are linked to wildlife use. In order to effectively restore tidal wetlands throughout the Estuary it is critical that we better understand the factors that affect both large- and small-scale patterns of plant distributions. There is evidence that minor shifts in elevation and inundation (presence/absence of creeks) can affect plant distributions, and our research will help to further understand these patterns.

SPATIAL VARIATION ACROSS WETLANDS



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TAKE HOME POINTS

- **Elevation is important, but other factors also affect plant distribution.**
- **More analysis is needed to evaluate the relationship of inundation and plant distribution.**
- **Plant diversity increases with elevation up to mean high higher water in Napa River wetlands.**
- **Plant distributions—along with physical factors—can be good predictors of wildlife use of tidal wetlands. These relationships give valuable insight into restoration design.**

Monitoring Bird Response to Restored Marshes

MARK HERZOG, ET AL.
PRBO CONSERVATION SCIENCE

Significant restoration is occurring around the Bay. We need to evaluate restoration success, and birds offer an excellent way to do that. The presence and function of particular species of birds in a given marsh are determined by physical and biotic factors, as well as demographic constraints imposed by their life histories. Collaboration with research teams in other disciplines, working at the same locations, has greatly enhanced our ability to study interactions of birds with vegetation, which provides food for prey species and substrate for nesting. As part of our multi-disciplinary studies, we are investigating how bird populations may be limited or influenced by landscape-level factors, and hydrological and geomorphic processes. We are building models that examine how heterogeneity of physical processes,

plants, habitat, and landscape affect the structure and ecological function of the tidal marsh bird community. While not an exhaustive list, specific variables we examined included salinity, vegetative species composition, distance to specific landscape features (such as pond, channel, urban, Bay, etc.), and a variety of channel metrics (channel order, linear density, areal density, etc.).

Using spatially predicted models, we are able to provide resource managers with current information on species abundances and distributions within restored and mature marshes and to assess the conservation and restoration efforts within the region. In addition, these analytical tools allow us to locate areas of the marsh or types of marsh where our predictions are less certain (i.e., where the model performance is poor), and therefore will benefit from additional sampling and research.

The PRBO adaptive monitoring protocol, which is currently being developed for the tidal marshes in the San Francisco Estuary, will provide a powerful, yet cost-effective approach to monitoring avian populations.

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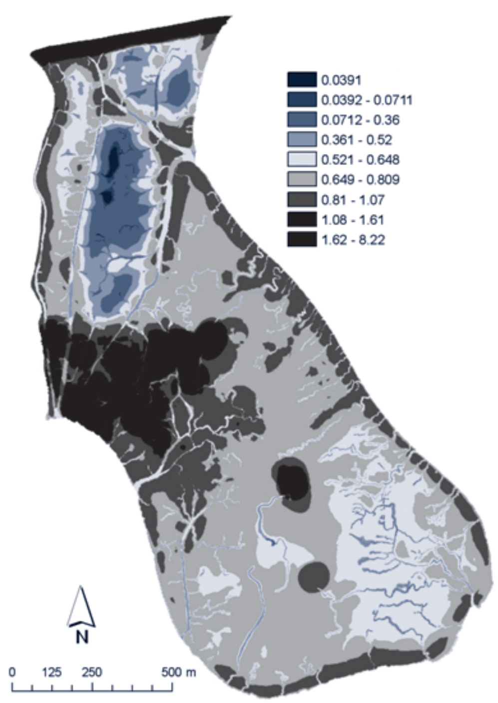
TAKE HOME POINTS

- **Spatial modeling provides an excellent tool to evaluate restoration.**
- **Spatial modeling also provides a way to address the uncertainty in our model predictions.**
- **Adaptive monitoring will enable researchers to monitor more efficiently, where the goal is as much to learn as it is to monitor.**

PREDICTED COMMON YELLOWTHROAT DENSITY
BIRDS/HA AT COON ISLAND



Design Guidelines for Tidal Wetland Restoration

PHYLLIS FABER, ET AL.
PHYLLIS M. FABER AND ASSOCIATES

Since the early 1970s, over 45 tidal marsh restoration projects have been implemented around San Francisco Bay, restoring tidal action to more than 2,800 acres. More than 20,000 acres are now being planned and designed. As of 2005, we have 33 years of restoration history and up to 19 years of systematic monitoring data from projects in San Francisco Bay. We have sufficient information from these monitoring efforts, and from 'snapshot' observations of other restored sites, to provide guidance on pragmatic practical design questions often encountered in restoration practice.

Funding from the State Coastal Conservancy to The Bay Institute has allowed the evaluation and documentation of this experience to produce a Design Guidelines report. The target audience is all those concerned with practical restoration questions in San Francisco Bay and includes resource management and regulatory agency staff and environmental professionals involved in tidal wetland restoration. Many of these design questions are relevant to resource managers in other estuaries.

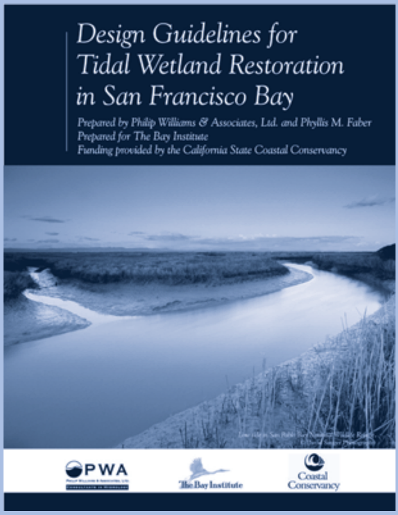
We structured the Guidelines to identify and assess key design issues by

1. Explaining our conceptual model of how restored marshes evolve and function based on our own observations and other researchers' assessments of restored marshes.

2. Describing the planning context used in restoration practice that creates the framework for design decisions and considering site-specific factors as well as geographic variability in the environmental setting and variation in project objectives.

3. Addressing the major design questions that dictate the grading of the site 'template' prior to reintroduction of tidal action.

We recognize that restoration practice is still in its infancy, with considerable uncertainties and unknowns. Early projects were focused on achieving a vegetated marsh as soon as possible; we now know that interim habitats and an evolving mosaic of habitats are also important. We anticipate that new insights will be provided in future years by continued monitoring data from restored sites.



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DESIGN QUESTIONS

Should the site be filled?
Should fill be removed?
Should a levee breach and outboard channel be excavated?
Should wave breaks be constructed?
Should the bayfront levee be lowered?
Should new tidal channels be excavated?
Should the pre-existing drainage system be modified?
Should the site be graded to encourage panne formation?
How should the wetland-upland transition be designed?
Should soil be treated?
Should plants be planted?
How do we provide habitat features for target species?
How should public access be provided?
How should we integrate flood management issues?

TAKE HOME POINTS

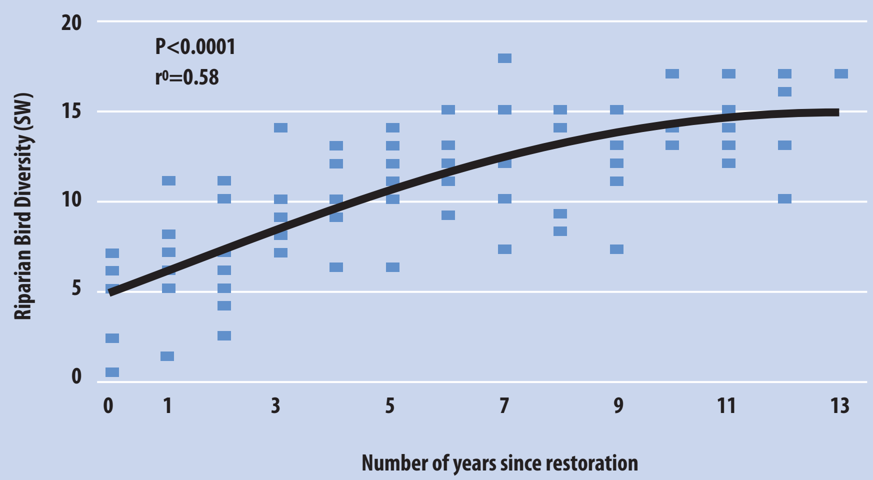
- **Examine physical processes carefully.**
- **Link design decisions with predictions of how the site will evolve.**
- **Have clear objectives at the outset.**
- **Better understand the functions and habitat values of the transition zone.**
- **Consider the legacy of past human actions.**

Using Birds to Assess Habitat Restoration

GEOFFREY GEUPEL
PRBO CONSERVATION SCIENCE

PRBO Conservation Science has been monitoring songbird populations using multi-tiered methods in restored and remnant riparian habitat in major watersheds of the Central Valley for the past thirteen years. Objectives include identifying existing areas of high bird diversity for protection and enhancement, establishing habitat relationships, and quantifying population response to changes in habitat including pre- and post- restoration, as reflected in the distribution, abundance, and demographic parameters of a broad spectrum of species. In addition, we study stopover use and weight gain during migration and site persistence during winter. Results are used to guide specific restoration practices and develop quantitative performance measures and biological objectives for bird populations at various spatial scales across the Central Valley. At mature sites along the San Joaquin River nest substrate selection for three species was positively correlated with forb cover and shrub cover, underlining the importance of planting and managing for understory species and structure. The novel focus on restoring understory on a three year-old restoration site on the San Joaquin National Wildlife Refuge has influenced the return of two locally extirpated species: the yellow warbler (from 0 to 14 nesting pairs) and the first documented pair of least Bells' vireos breeding in the Central Valley in over 60 years. While abundance of birds at restored sites show promising increases in abundance and species diversity during spring, fall, and winter, nest success of many species, especially in remnant forests, remains problematic and may be too low to sustain populations over time in the absence of restoration of floodplain dynamics or other conservation actions.

INCREASE IN BIRD SPECIES & DIVERSITY ON THE SACRAMENTO RIVER



TAKE HOME POINTS

- Birds are indicators of ecosystem health. Different species have different requirements that represent a range of critical ecosystem and habitat elements.
- Monitoring ecosystems with birds uses cost-effective, established methods that can be applied across multiple scales.
- Results from bird monitoring may be used to adaptively manage restoration and enhancement projects.
- Birds can be used to "audit" the success of restoration and help set quantifiable biological objectives.
- We plan to maintain long-term monitoring sites as reference sites for new sites and to assess the sustainability of bird populations.
- We recommend including extensive bird monitoring in all restoration projects, and continue to adapt and test recommendations at multiple sites.

National Wildlife Refuge is attributable to planting large dense patches of shrubs and groundcover—which prevent invasive species—interspersed with trees, as well as meadow species (forbs and sedges) that increase understory diversity. It is important to provide seed source areas for future dispersal.

- Birds are responding positively to restoration activities. Revegetation is working to restore a diversity and abundance of songbird populations along the Sacramento, Cosumnes, and San Joaquin Rivers.
- To ensure diverse and viable population of songbirds, we need to manage for a mosaic of riparian habitat that includes a healthy proportion of early-successional stage habitat (e.g. contains dense herb cover and a diverse understory). This may require intensive management (e.g. mechanical disturbance) if the site is not periodically disturbed by flooding and/or if the river is disconnected from its floodplain.

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Will Restored Tidal Wetlands Benefit Bay Food Webs?

CHARLES SIMENSTAD, ET AL.
UNIVERSITY OF WASHINGTON, SCHOOL OF AQUATIC AND FISHERY SCIENCES

Understanding food webs in complex estuaries such as the San Francisco Bay-Delta requires comprehensive knowledge about how heterogeneity of the Estuary creates subsystems or compartments of interacting food web sources and consumers, especially when we are trying to predict or evaluate the potential role of restoration actions. The dominant base of our knowledge about the food web structure of San Francisco Bay is founded on a phenomenal accumulation of knowledge about open water, pelagic food webs based on phytoplankton—the "classic" food web of Hardy (1924). Even the complexities of the heterotrophic/microbial aspects are focused in the pelagic realm. The paradigm is that the Bay "runs" on phytoplankton.

However, there are shallow water and wetland ecosystems that once comprised, and now and could in the future comprise a significant compartment in the Bay's food web, that likely integrates with the pelagic compartment. Recent research using both traditional methods (food habits) and conservative biomarkers (stable isotopes) indicate that tidal emergent marshes not only support closely-coupled internal food webs but also provide linkages to the open Bay through direct and indirect exchanges of transient consumers and very likely organic detritus. Contrasting marsh residents (e.g., benthic invertebrates such as *Macoma balthica, Corophium spp.*, and *Ischadium demissum*; Pacific staghorn sculpin, yellowfin goby, Shimofuri goby, threespine stickleback, tule perch, rainwater killifish), and nursery residents (e.g., splittail, Chinook salmon) with more transient planktivores (e.g., Sacramento splittail, northern anchovy, Pacific herring, inland silversides, topsmelt) and predators (e.g., striped bass) indicates that not only does autochthonous production dominate the emergent wetland food webs but also that it contributes to the broader Bay food web. Evidence from stable isotope analyses suggests that both edaphic microalgae and emergent marsh macrophytic organic matter contribute significantly to transient species, while phytoplankton is a comparatively minor contributor.

The highly dynamic nature of these food web "loops" is evident from the variability in contributions of organic matter sources, and is often tied to consumer life histories and behaviors, as well as responses to disturbance events, such as freshwater flooding.

The magnitude and significance of both wetland "outwelling" and influx of organic detritus and living algal cells is still unresolved. From the "marsh perspective," there is emerging evidence of both nekton and food web interactions between peripheral (and restoring) wetlands and Bay-Delta open water ecosystems, but we lack a system view of their significance. A landscape view that considers fluxes of organic matter and organisms across the estuarine mosaic, and considers tidal and freshwater flooding forcing, would be a more appropriate assessment of the role of both open water and wetland food web contributions and interactions. Such a more integrated "intercompartmental" and dynamic view of San Francisco Bay-Delta food webs would enhance our ability to understand both the basis of and variability in support of important consumer organisms as well as the comprehensive role of wetland restoration in the Bay-Delta.

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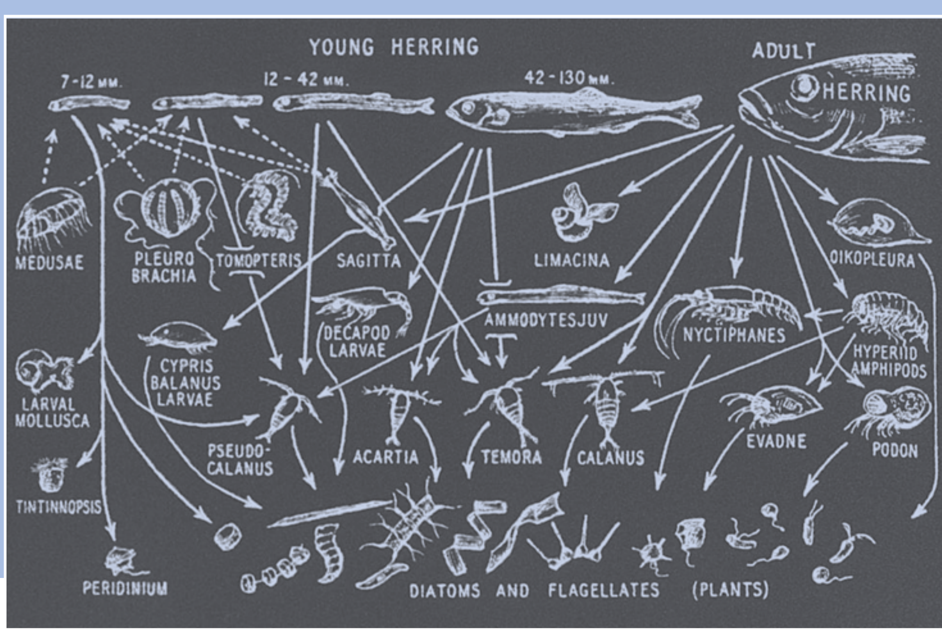
TAKE HOME POINTS

- **The Delta is a detritus mill for the Bay, exporting 30-40 percent of its organic matter to the downstream food web.**
- **We still do not know all of the sources of that organic matter but are using stable isotopes to try to determine them.**
- **The interactions between tidal wetlands and pelagic areas are still not well understood.**



Hardy's Food Web, 1924

The Importance of Suisun Marsh in Estuarine Productivity

ROBERT SCHROETER AND PETER MOYLE
UNIVERSITY OF CALIFORNIA, DAVIS

Estuarine tidal marshes are productive habitats that provide the conditions and microhabitats necessary for successful invertebrate and fish rearing and recruitment. They may also provide, through export, a source of productivity to surrounding habitats. Tidal marsh habitat in the San Francisco Bay-Delta Estuary has decreased by 90 percent over the past 150 years. The impact of this loss and the ecological contribution of the remaining tidal marsh habitat in the Estuary are not well understood. We investigated the productivity of tidal channels in Suisun Marsh, Solano County, the largest contiguous brackish tidal marsh on the West Coast of the United States, and compared our findings to data collected by the California Department of Fish and Game in adjacent bay and river habitats (*neomysis* and zooplankton surveys).

Primary production, as measured by chlorophyll a, indicates several regions of high productivity within the interior of the marsh, likely due to high residence time of water, nutrient availability, and absence of alien clams. Surrounding bay and river channel habitats had very low levels of primary production. Invertebrates, including mesozooplankton and benthos are most abundant within the interior sloughs and channels, often reaching very high densities. Macrozooplankton abundance patterns are more variable, but are also high within the marsh interior and rivers with declines observed in some bay and large slough habitats. These data suggest that Suisun Marsh plays a significant role in estuarine productivity by providing an abundant source of primary production and pelagic invertebrates, both of which are significantly depleted in bay and river channel habitats. These localized areas of high productivity may transfer benefits up the food chain, as fish abundance for select species remains high in the tidal marsh sloughs despite considerable declines observed elsewhere in the Estuary. There is little evidence that this productivity is directly transported to the exterior bay and channel habitats, although migratory invertebrates and fish may export considerable quantities of biomass from the marsh through their movements.

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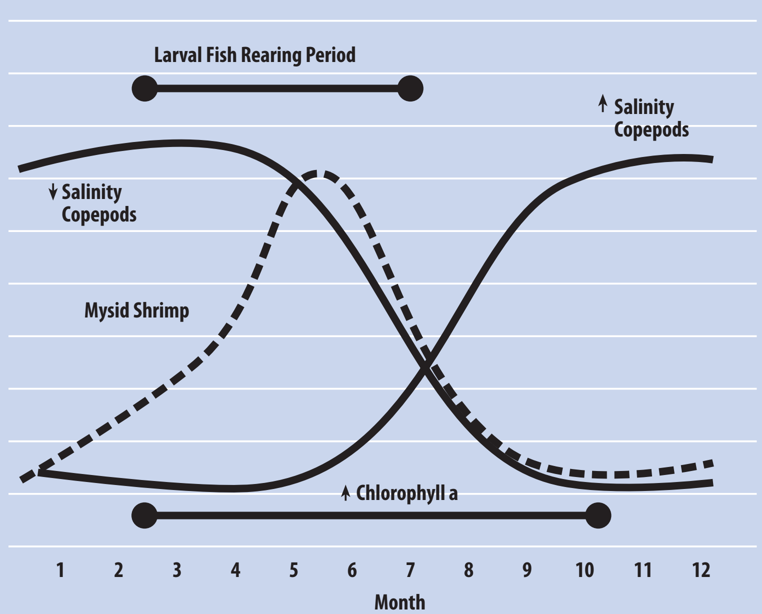
SEASONAL PREY AVAILABILITY IN SUISUN MARSH



TAKE HOME POINTS

- **Tidal marshes are important rearing areas for fish and invertebrates.**
- **They are refuges for native species and are highly productive—maybe the most productive—habitats.**
- **Many key fish species—Delta smelt, longfin smelt, splittail, and striped bass—are declining throughout the Estuary.**
- **Fish abundance in Suisun Marsh does not follow Estuary-wide trends—Suisun Marsh had increases in striped bass and splittail.**
- **The differences are likely due to good prey availability during key seasons and high phytoplankton biomass within Suisun Marsh. This abundance is related to the complexity of the tidal marsh habitat found there.**
- **Factors limiting productivity in the bay and river channels surrounding Suisun Marsh include the overbite clam, an efficient filterer of the water column, and discharge from duck ponds of organically rich waters, resulting in poor water quality.**

Chinook Salmon and Steelhead in the Bay and Central Valley Rivers

STEVE LINDLEY, ET AL.
NATIONAL OCEANIC
AND ATMOSPHERIC ADMINISTRATION

To help guide recovery planning for threatened and endangered chinook salmon and steelhead in the Central Valley and San Francisco Bay, we are developing biological viability goals for populations and evolutionarily significant units (ESUs) of these species. We infer the historical population structure from a combination of historical records and GIS-based habitat modeling, develop simple criteria for population status based on genetic and demographic models, and assess historical and current spatial structure of ESUs in relation to sources of catastrophic risk using tools from graph theory.

The winter-run chinook salmon ESU consisted of four populations prior to the dam building era; all four were extirpated from their natural spawning range, but are represented by a single population utilizing the tailwaters of Shasta Dam. This population of winter chinook satisfies the criteria to be considered a viable population, but cannot be considered a viable ESU by itself, because it is vulnerable to several catastrophic risks that could easily extirpate the population, and therefore, the ESU. The spring-run chinook salmon ESU is represented by two or three extant independent populations, and over 20 have been extirpated. Like the winter-run chinook population, the extant populations are probably viable in the short term, but because these populations are quite close together, this ESU is at elevated risk of extinction due to catastrophic risks that would not have threatened the historical ESU with extinction.

The situation with steelhead is much murkier. There may have been on order of 80 or more independent populations of steelhead, and much of the spawning habitat used by these populations now appears to be behind impassable dams. It is possible that descendents of the historical steelhead populations persist as resident trout, and new populations may exist in tailwater areas below some dams.

Overall, it appears that habitat conditions in accessible areas have improved, as indicated by the improving status of extant populations. More broadly, however, the large majority of historically used habitat is not accessible to anadromous fish, and the presently restricted distribution of the ESUs keeps them at elevated risk of extinction. Further improvements in the status of chinook salmon and steelhead may require access to currently inaccessible habitat.

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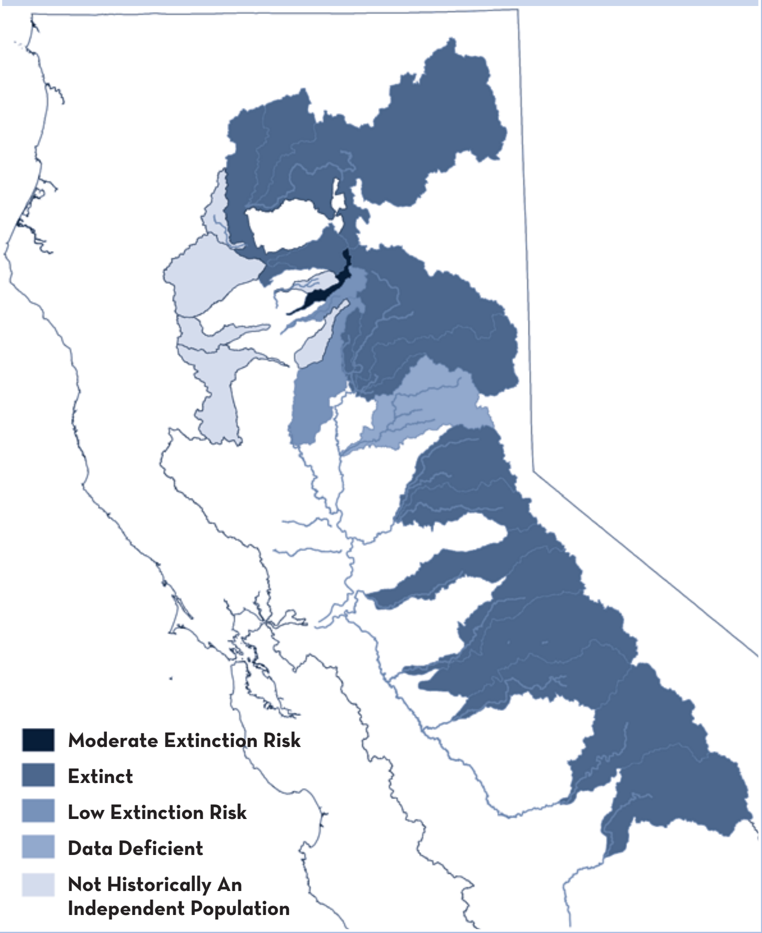
STATUS OF CENTRAL VALLEY SPRING-RUN CHINOOK SALMON POPULATIONS



TAKE HOME POINTS

- **Only tiny remnant populations are left. We are going to have to do some creative thinking about how to preserve ESUs.**
- **Eighty percent of our stream reaches are now behind impassable barriers.**